

Plug-In Hybrid Electric Vehicles and Wind Energy

OVERVIEW OF PHEVS

We present an analysis of the synergisms between wind energy and plug-in hybrid electric vehicles (PHEVs). PHEVs are a possible next evolutionary step from the hybrid vehicles that are quickly entering today's light-duty vehicle (LDV) markets. By adding additional batteries and an external charging capability, PHEVs will derive some of their drive energy from grid electricity, increasing electric loads on the grid while reducing gasoline consumption and carbon emissions from vehicles.

PHEVs could be designed to not only charge from the grid, but also to discharge small amounts of energy to the grid for reserve power. Utilities require several forms of reserve power that can be classified by the response time and the duration of the power requirement. Battery power is an excellent source of reserve power for quick-response, short-duration utility requirements that don't require much energy from the battery. Due to the limited amount of energy that can be stored, PHEV batteries are an excellent source of minute-to-minute regulation reserve, a possible source of operating reserves required for 10-30 minutes, and a limited source of contingency or planning reserves that can require energy for several hours at a time.

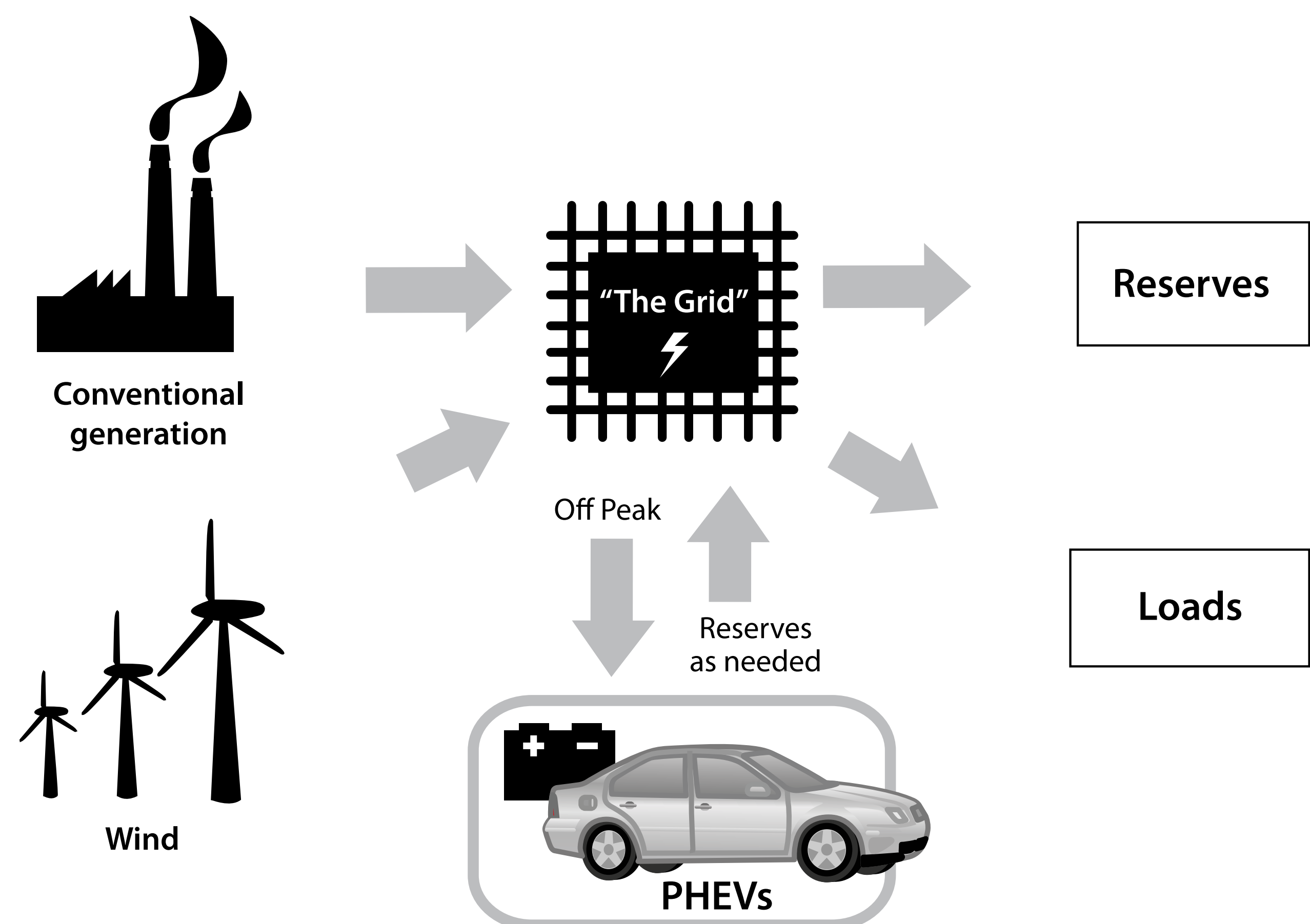


Figure 1: PHEVs and the Electric Grid

ABOUT THE WINDS MODEL

The variability in wind generation precludes wind from contributing fully to meeting a utility's planning reserve, generally increases a utility's need for operating reserve, and can slightly increase a utility's need for regulation reserve. However, if PHEVs were

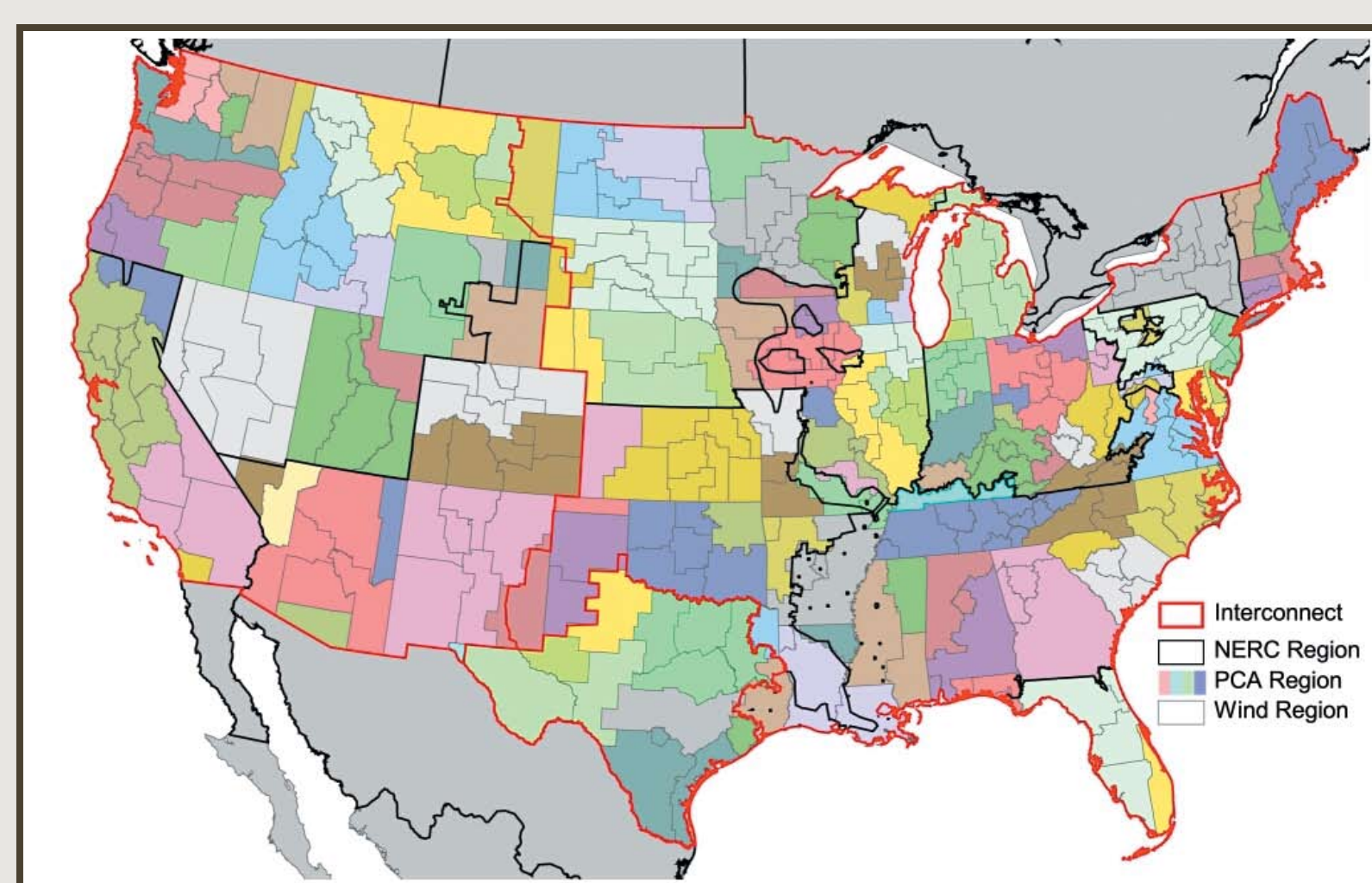


Figure 2: Regions in the Wind Deployment System (WinDS) Model

available in large quantities to provide such reserves, the variability of wind generation might be much less of a drawback for wind power.

To assess the benefits and impacts of PHEVs on the electric grid, the authors used the Wind Deployment System (WinDS) model – a computer model originally designed to evaluate the potential for wind energy generation in the United States. WinDS optimizes the regional expansion of electric generation and transmission capacity in the contiguous United States. With its large number of regions (see **Figure 2**) and probability-based assessments, WinDS is able to focus on grid-integration issues such as wind resource variability and transmission.

The primary outputs of WinDS are the amount of capacity and generation of each type of prime mover – coal, gas combined cycle, gas combustion turbine, nuclear, wind, etc. – in each 2-year period from 2000 to 2050. The WinDS results shown in **Figure 3** are from

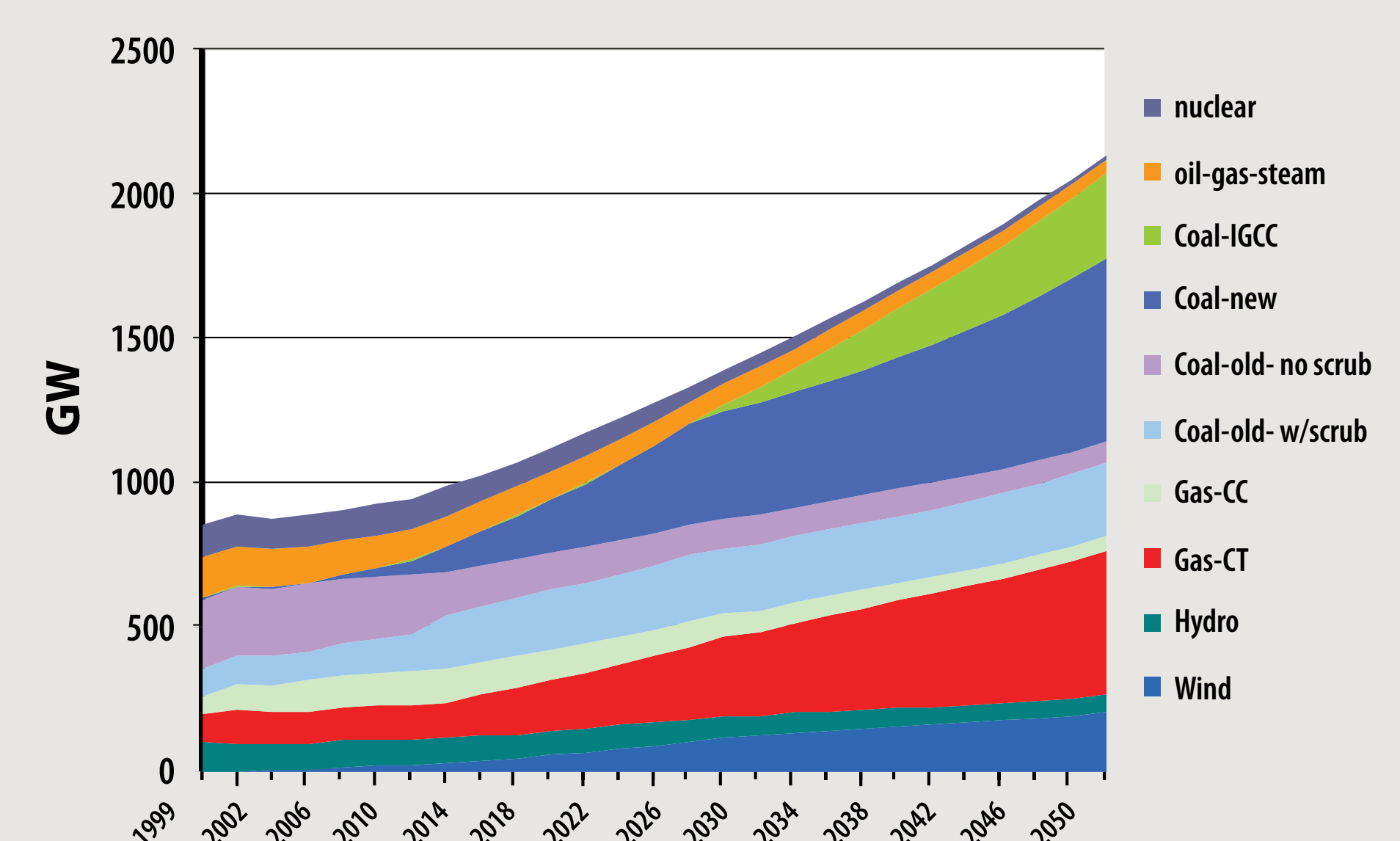


Figure 3: WinDS Base Case Capacity Results

the 2005 base case, which is largely defined by input assumptions for fuel prices, conventional generator cost and performance, and electricity demands taken from the EIA annual Energy Outlook 2005 reference case.

THE RESULTS FOR PHEVS

Within WinDS, grid reliability is captured by two constraints on planning reserves and operating reserves. To model the impact of PHEVs on the grid – and particularly on wind – we estimated the contribution of PHEVs to these WinDS reserve constraints. **Table 1** shows the results for a PHEV that can travel 20 miles on its electric charge (PHEV-20)

Table 1: PHEV Contribution to Utility Reserves

Parameter	PHEV-20	PHEV-60
Fraction of LDV stock in 2050	50	50
% Plugged in	50	50
Battery Size (useful capacity kWh)	5.9	17.7
Battery State of Charge (%)	60	70
Operating Reserve Capacity (kW per PHEV)	3.5	5.8
Planning Reserve Capacity (kW per PHEV)	0.4	1.5

and one that could travel 60 miles on a single charge (PHEV-60). Their contribution to each type of reserve is determined by the number of vehicles, their battery size, the fraction plugged in at any one time, their average state of charge, and the length of time the reserve might be required.

Table 2: PHEV Electric- and Transportation-Sector Impacts

2050 Projected Values	Base Case (no PHEV's)	PHEV-20 Case	PHEV-60 Case
Wind Capacity (GW)	208	238	443
Total Electric Load (TWh/year)	9,392	9,808	10,082
LDV Gasoline Use (Billion gallon/year)	142	107	85
Electric Sector CO ₂ (10 ⁶ tons/year)	7,273	7,538	7,220
LDV CO ₂ (10 ⁶ tons/year)	1,422	1,066	853
Total CO ₂ (10 ⁶ tons/year)	8,695	8,604	8,073

Table 2 shows the impact of PHEVs on load, gasoline use, and carbon emissions in both the electric and transportation sectors. In the PHEV-60 case, national annual electric loads in 2050 are increased less than 8% by PHEV charging, while gasoline use by LDVs decreases 40%. Total carbon dioxide emissions also decline by about 7%, while wind installations increase by more than 100%.

With these additional PHEV-provided reserves penetrating into the market between now and 2050, WinDS projects that wind energy will increase from the 208 GW of the base case to 238 GW and 443 GW, respectively, with PHEV-20 and PHEV-60 vehicles (**Figure 4**).

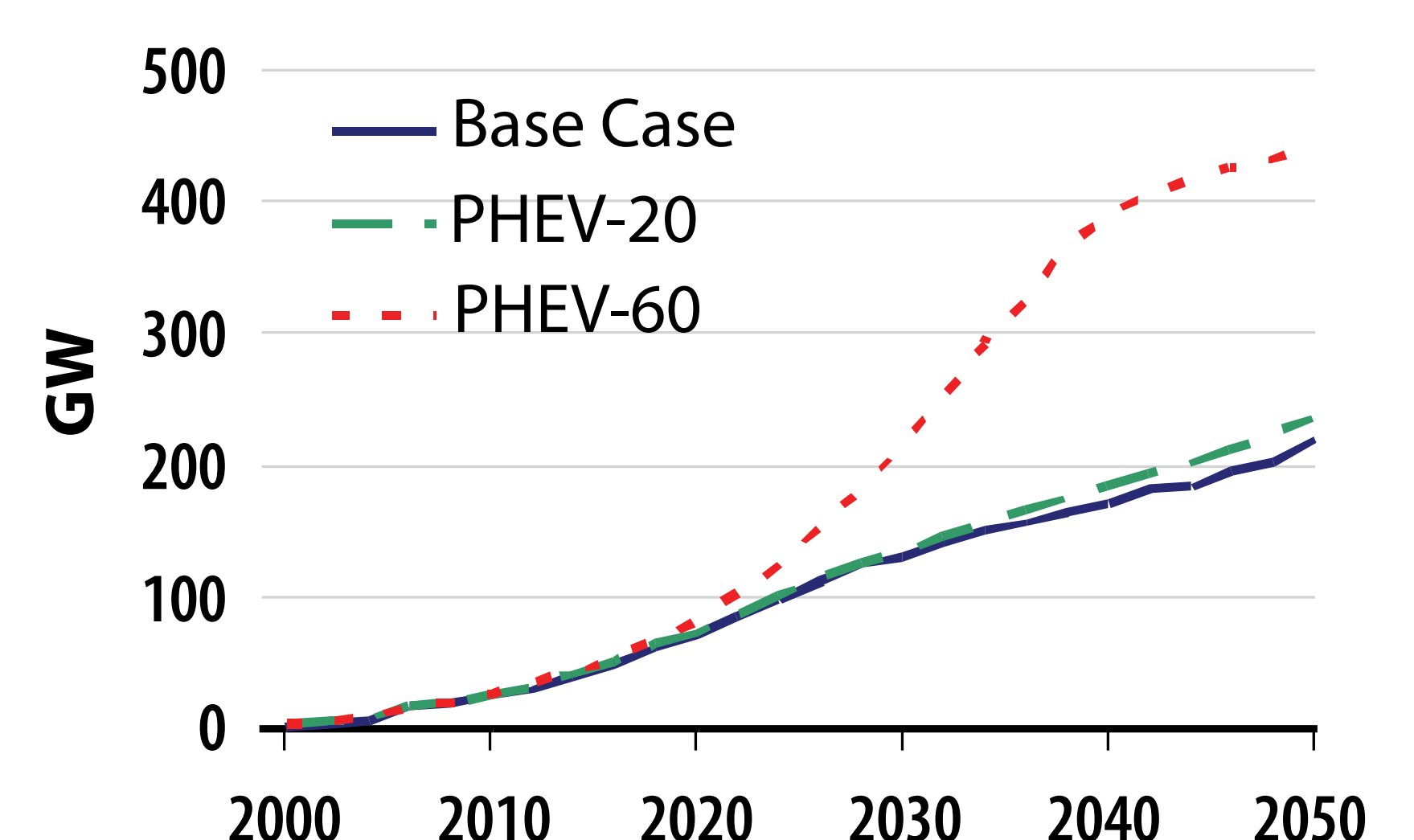


Figure 4: Wind Penetration with PHEVs

CONTACTS

Walter Short and Paula Denholm
walter_short@nrel.gov
paula_denholm@nrel.gov

National Renewable Energy Laboratory (NREL)
1617 Cole Blvd.
Golden, CO 80401-3393